LOAD RESEARCH

Sri Lanka Sustainable Energy Authority

Study Team

Upali Daranagama

M M R Pathmasiri

Ramani Nissanka

Chamila Jayasekara

K S Kithsiri

Vijitha Ekanayake

Jude Sakaraja

Irosha Kalugalage

P S Sanjeewa

Pubudu Bandara Bamunawala

Lakshman Chandrarathna

Dayan Karunarathna

Kalpana De Silva

Saman Kulasuriya

ACKNOWLEDGEMENT

This work would not be successful if the cooperation of many of the staff of the Ceylon Electricity Board (CEB) was not received. Among all we highly recollect, and thankful to the General Manager and the Assistant General Manager (R2) of the CEB for the immense cooperation given in the conceptual stage. Further we highly appreciate the commitment and the assistance given by Mr. N P S Karunarathna, the Deputy General Manager of North Western province, CEB and Mr P W M N A B Wijekoon, Chief Engineer of Kurunegala branch.

1.0 BACKGROUND

The electricity sector in Sri Lanka is advancing rapidly, both in terms of the demand and in the level of penetration of services. Therefore, the sector posses a tough challenge to the government, more specifically to the utility, to infuse and maintain the necessary generation and transmission capabilities. Furthermore, the daily load curve is highly skewed, with a high peak lasting for a short duration. This has been an additional burden to the utility, whereas a flatter load curve would have made existing plants operate more evenly reducing the necessity of adding new plants to manage the high peak.

It is observed that the high evening peak is predominantly due to the lighting load hailing from the household sector. Further, it is expected that the expansions in the rural electrification schemes and the provision of electricity to the Eastern and Northern parts of the country in an accelerated program will make this situation even more severe. Therefore, it is of paramount importance to understand demands and modes of lighting prevalent at the consumer end, and its burden on the national system, in order to devise effective modalities to ensure the optimum usage of available resources, launch efforts to educate general public and popularize better means of lighting, if necessary. Taking these issues into account Sri Lanka Sustainable energy authority (SLSEA) in collaboration with the Ceylon Electricity Board (CEB) took steps to conduct a consumer survey.

1.1 OBJECTIVE OF THE STUDY

The electricity utility of the country, the Ceylon Electricity Board records the daily demand curve. This information is widely used to make number of important decisions in the power sector such as forecasting of future demands, identifying the daily peak demand and devising necessary mechanisms to meet this demand, identifying seasonal variations and matching it with the availability of plants and the fuel mix etc. However, very little information is available on the constituent components of the electricity demand curve. Therefore, it is a daunting task to develop policies, guidelines, capacity/awareness building programs to target manufacturers, vendors and users in different sectors and to promote the optimum use of electricity without having a proper understanding of their requirements and preferences in using electricity and types of equipment. In this light, load research activities at the end user point generate the much needed information.

The specific objective of this research activity is to identify the patterns of utilizing electricity in the households in different tariff categories in the selected area. Further it is expected to determine how different loads (lighting, refrigerator, entertainment etc.) contribute to the overall consumption, in this case, more importantly the lighting load. The information on different equipments used, and usage of equipment in different times of the day will also be collected and analyzed. This exercise will be the foundation to identify suitable demand side management measures and the appropriate modes introducing them.

2.0 GENERAL APPROACH AND METHODOLOGY

As it is not practically viable to study the electricity usage patterns of the entire country, and hence a representative sample of consumers was selected. Further, other concerns like the facility to extract accurate information both from the users and from the utility, the easy supervision and management of data collection and analyses processes are deemed important for the successful completion of the project, was considered while selecting the sample. Also considered the consumption pattern of the domestic sector in the country such that the percentage of consumers in each category according to the tariff set (eg. 0 - 30 units block etc.) and the sample also selected very similar to national scenario of domestic consumption.

In considering the above factors and the representative nature of the consumers, it was proposed to conduct this study in Mallawapitiya in the Kurunegala Area Engineers' division of the CEB. The sample contained 2911 households that draw power from 10 transformers. Sample listing and selection was carried out by a professional staff at the Department of Census and Statistics. Below describes the steps followed from the point of sample selection to the data analyzing process.

(a) Development of the survey methodology

The survey was conducted with two different components. The first component was to obtain information about the usage of different electrical appliances, their power consumption and the time of their operation etc. The information was gathered by a questionnaire consisting of thoroughly screened set of questions which were designed to capture basic load profile of the selected sample and to identify the equipment, their characteristics and their contribution to the total load. The questionnaire also comprised with the questions formed to reckon the resident's knowledge on energy saving tips of electrical appliances. The load profile of households was identified from this first component and it was further verified by the second component which measured actual load profile of the sample, using data loggers connected to the 10 transformers as mentioned above. In both cases, it was expected to capture weekly load patterns incorporating any change in user patterns during the weekends.

The consumers in the selected sample were further subcategorized depending on their consumption based on the tariff blocks of the domestic tariff (less than 30 kWh per month, 31-90 kWh per month,.. etc). This was used to decide the urban, semi-urban and rural parts of the area within the scope. Identification of this was useful to determine the variation of consumption patterns of the different sectors. Illustrated below is the basis on which the urban, semi-urban and rural areas were determined.

Table 1: Base for determination of the sector

Sector	Percentage households with consumption more than 90 kWh/ month
Urban	0-15
Semi-urban	16-30
Rural	31-45

Thus if number of households with electricity consumption more than 90 kWh/month is less than 15% of the total number of households in a particular area that area was considered as rural. If number of households with electricity consumption more than 90 kWh/month is in between 16% - 30% of the total number of households that area was considered as semi-urban and if more than 31% of the total number of household consume more than 90 kWh/month that area was considered as urban area.

The details of the methodology followed are described below:

i. Questionnaire method

   The questionnaire (see Annexure A) was given to each household of the total sample. The verbal information obtained from the residents (for the questionnaire) was recorded at their door step by the surveying teams who had been well trained for the job. Thus the probable mistakes in filling the questionnaire was avoided, otherwise if the questionnaire was to fill in by the residents themselves lot of mistakes could be happened since the comprehensive level of different people may vary.

ii. Forming the surveying teams

   Originally 50 people were employed to conduct the survey. These individuals were students of technical colleges. Twenty five teams were formed out of these 50, by allocating two people per each team. These 25 teams visited 2911 households during the period of survey. Five officials (one for every five teams) were appointed to work onsite with the teams to attend when the teams need advice on the matters that may arise during the survey.

iii. Training surveying teams

   A comprehensive training was given to the group of 50 individuals who were recruited in the field to conduct the survey. They were trained to capture data required as mentioned above and record them accurately. Moreover, they were trained to attain skills of interviewing people to obtain accurate information with minimum disturbance to the sampled population, and skills on interpreting descriptive information to match the data requirements of the questionnaire. After the training session each individual was assessed as follows to see their level of grasp.

   - The group was asked to fill in the same questionnaire based on the electricity consumption pattern of their own homes. Once this was done each completed questionnaire was considered individually and discussed within the group. Once this was done each completed questionnaire was considered individually and discussed within the group. Further they were given an assignment to fill in two more questionnaires by interviewing two neighbours. The filled questionnaires were again discussed and thus the group had chance to achieve maximum comprehension of the task.

iv. Actual measurements using power analyzers

Real time power measurements were taken at 3 different points as follows:

- At the transformers from which electricity was drawn to the selected sample of houses. Actual power consumption of the sample was monitored using power analyzers connected to the 10 transformers from which the selected sample of houses was drawing electricity. Power analyzers were fixed to the transformers by the skilled technical staff of the SLSEA and CEB and data logged for two weeks duration.

- At the main feeder
  Load profiles of the main feeder, at the relevant distribution substations was also measured to check the information collected and to ascertain the share of the domestic users fed by them.

- At the power meter of individual houses
  Power consumptions of individual houses were also monitored. Power analyzers were fixed to the main panels of selected houses of the sample thus facilitating data logging of power consumption during the time of concern. The data were then analyzed to see whether there was any discrepancy in the actual consumption and the consumption estimated using the responses to the questionnaire.

(b) Data collection and analyzing

The data gathered from the questionnaire and the data downloaded from the power analyzers were put in suitable formats to study further and necessary analysis.

3.0 OBSERVATIONS AND RESULTS

The area chart shown below gives the daily demand pattern of the sample which was

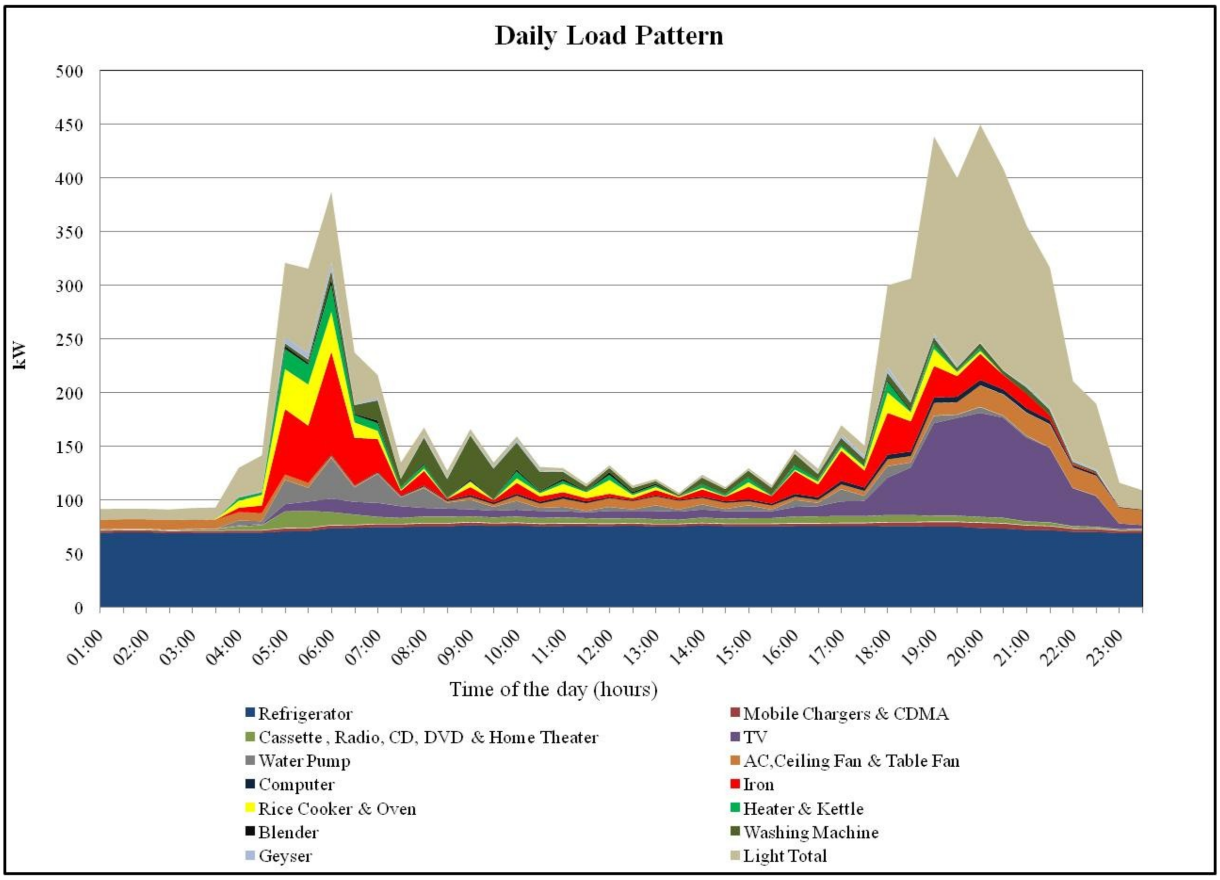

Figure 1: Daily demand pattern

The daily demand pattern shows two significant peaks, one appears to be occurred around 5:30 - 6:30 in the morning and the other around 7:00 - 8.00 at night (For easy reference these two peak loads are referred to as Morning peak and Evening peak). It shows that the refrigeration load is a stable load attributing in the range 41% to 70% of the total load during the day time, and 16% of the evening peak load. During the day time refrigerator load happen to be the highest load. During 8:30 -10:30 in the morning the contribution from washing machines is significant accounting 24% of the total. The share of different appliances/items contributed for the morning peak and evening peak separately was also studied and illustrated by the pie charts as shown above.

Ironing load is highly significant in the morning peak and contributed nearly 20% of the total load during the morning peak. Hence if ironing load could be shifted to other time of the day, the morning peak would be reduced by 20%. Lighting load during the morning peak is similar to the ironing load. There is considerable power attributed for rice cookers and ovens during 5:00 - 5:30 in the morning and this is due to early morning domestic cooking.

Evening peak is attributed by the lighting load which accounts 43% of the total load. The second highest load during evening peak is the TV load which accounts 21% of the evening peak load.

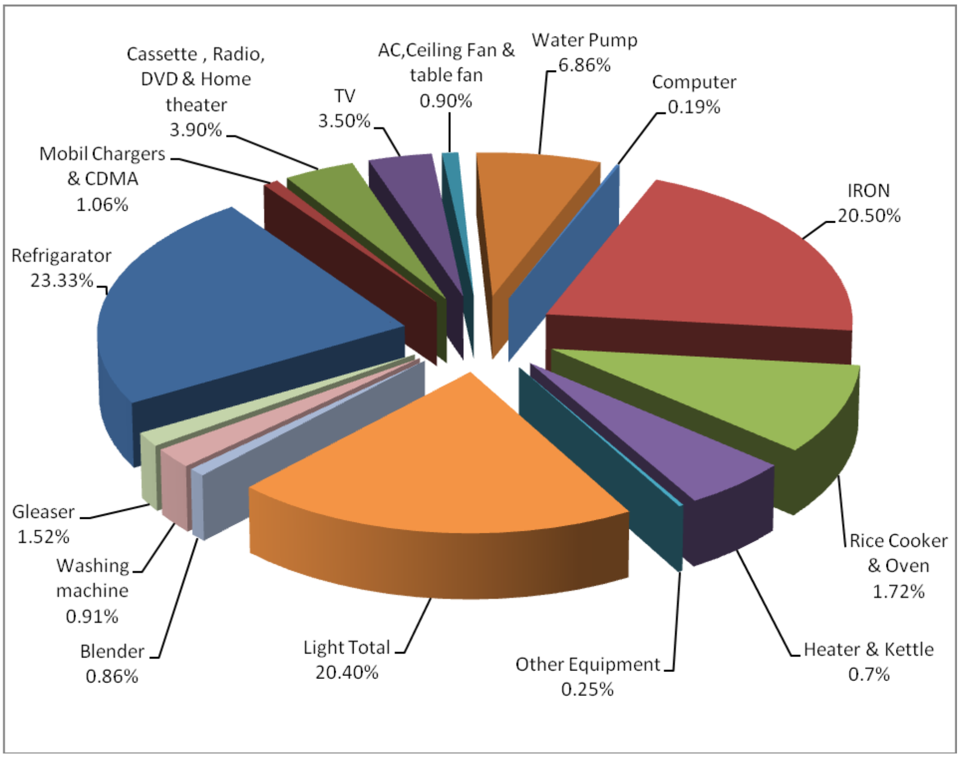

Figure 2: Share of electrical energy at Morning peak

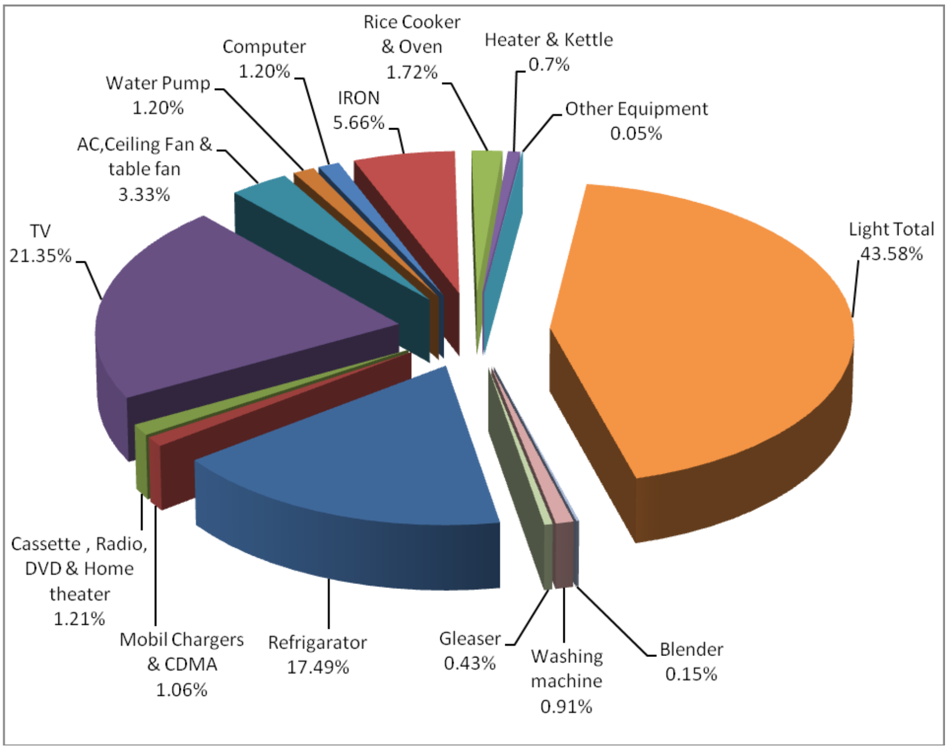

Figure 3: Share of electrical energy at Evening peak

Lighting load contributes significantly for the evening peak as well as the morning peak. Hence lighting load becomes the first to address to decide any approach to strategy it was further studied in different aspects such as the contribution to the total lighting load from different types of lamps types, usage of different types of lamps, how the usage get vary by the sector etc. Table below illustrates percentage use of different types of lamps from the total lamp population and the percentage contribution to the total lighting load from these lamps.

Table 2: Usage of different types of lamps and their contribution to the total lighting load

Lamp type	**% of lamps from total lamp population**	**(%) from morning lighting load**	**(%) from evening lighting load**	**(%) from total average lighting load**
CFL	47	30	31	27
Incandescent	49	66	64	68
LFL	3.3	3	4	4
Other	0.7	1	0.3	1

Above reveals that the number of CFLs and incandescent lamps used in households are nearly the same, but their contributions to the total lighting load are very different from each other. The contribution to the total lighting load from the incandescent lamps is 2.5 times higher than that of the CFLs. For easy reference this was illustrated by an area-chart as shown below.

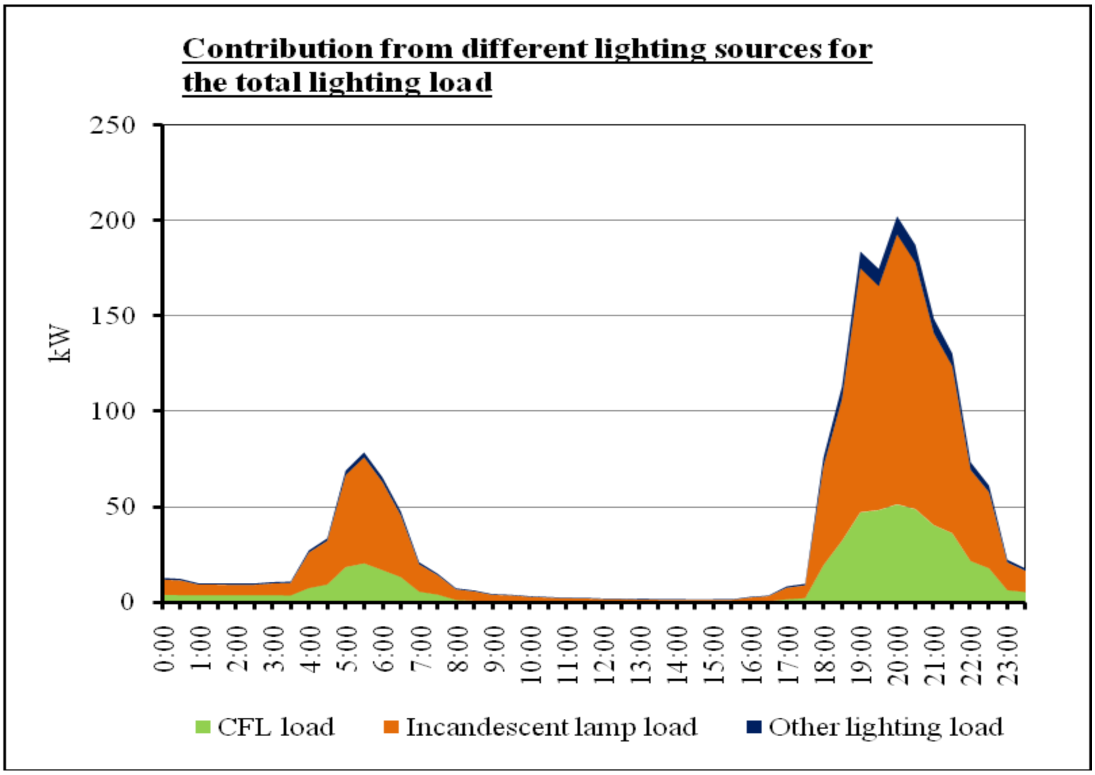

Figure 4: Contribution from different light sources to the total lighting load

According to the information by replacing the existing Incandescent lamps with CFLs 40% of total lighting load could be cut down and this would highly contribute to the reduction of peak loads and doing so new lighting load during the two peaks will appear as follows:

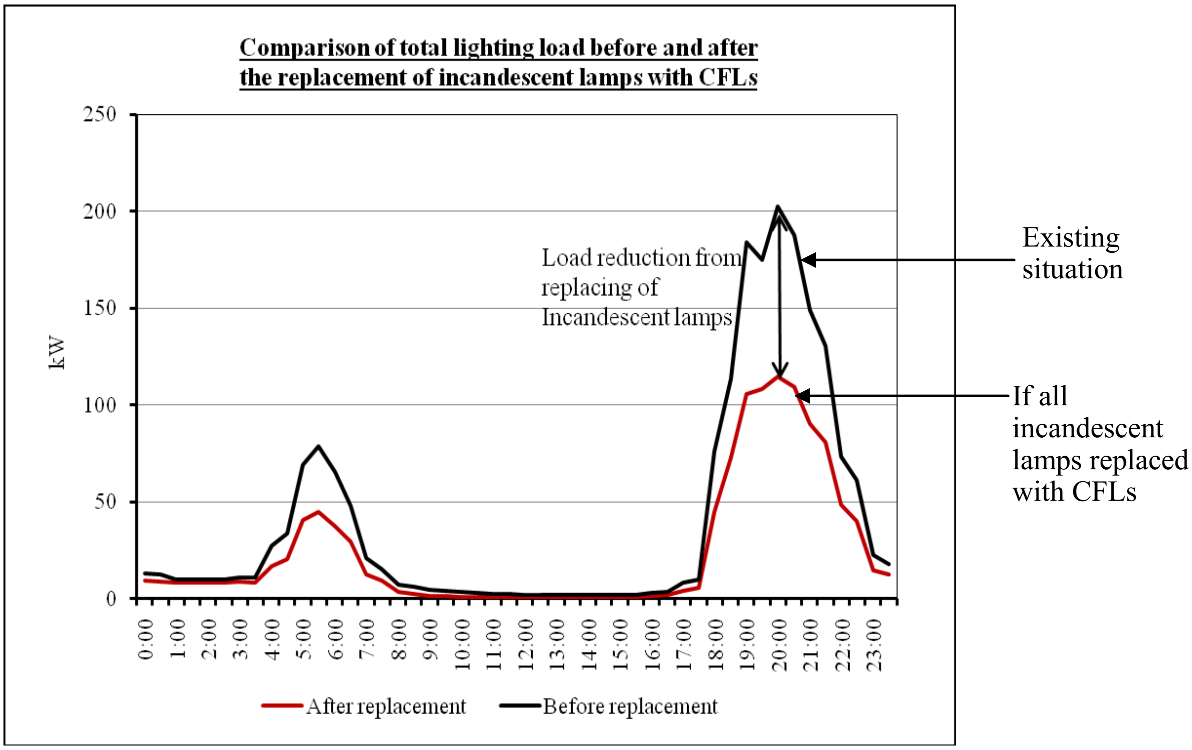

Figure 6: Reduction of lighting load by replacement of Incandescent lamps with CFLs

Sector-wise contribution from the different types of lamps to the total lighting load during morning peak and evening peak is illustrated in the Table below:

Table 3: Sector-wise contribution to the morning peak demand

Lamp type	Urban (%)	Semi urban (%)	Rural (%)
CFL	38.4	28.7	24.0
Incandescent	59.2	66.2	72.9
LFL	2.1	4.1	2.6
Other	0.3	1.0	0.5

Table 4: Sector-wise contribution to the evening peak demand

Lamp type	Urban (%)	Semi urban (%)	Rural (%)
CFL	40.3	30.6	23.0
Incandescent	57.4	62.5	72.6
LFL	2.3	6.0	4.1
Other	0.1	0.9	0.3

The information reveals that the contribution from incandescent lamps to the total lighting load is highest in rural sector while this is lowest in urban sector. This shows that the usage of incandescent lamps is comparatively higher in rural sector than in other two sectors. Further the contribution from LFLs is comparatively higher in rural and semi-urban than in urban sector.

This is further verified by the information shown in the table below which describes the percentage of different types of lamps that are in use.

Table 5: Sector-wise usage of different types of lamps

Lamp type	Urban (%)	Semi urban (%)	Rural (%)
CFL	62.6	53.5	42.0
Incandescent	35.6	41.2	54.2
LFL	1.6	4.1	3.2
Other	0.3	1.1	0.6

CFLs usage in urban sector is about 1.75 times higher than the usage of incandescent lamps. This is about 1.3 times higher in semi-urban sector. In rural sector usage of CFLs are lower than the use of incandescent lamps. However when analyzing the total sample it is evident that the usage of CFLs is almost equal to the usage of incandescent lamps and this is explained in column 2 of Table 2 above.

At the same time CFL penetration (number of houses with at least 1 CFL) was studied. Table below provides the information on CFL penetration.

Table 6: Percentage households having at least one CFL

Sector	% of households having at least 1 CFL
Urban	92%
Semi-urban	85%
Rural	75%

Highest penetration occurs at urban sector while the lowest at rural sector. However the data shows when compared with the past data that the penetration of CFLs has increased quite rapidly during the past few years in all the three sectors.

3.1 DATA VERIFICATION

Information provided above was basically used by the data obtained from the questionnaire. In order to verify this data it was compared with the actual readings obtained from onsite measurements of transformers to see whether there was any discrepancy in the two categories of data. The two curves illustrated in the Figure below represents the total transformer load and the total power consumption of households (obtained from the questionnaire during the survey).

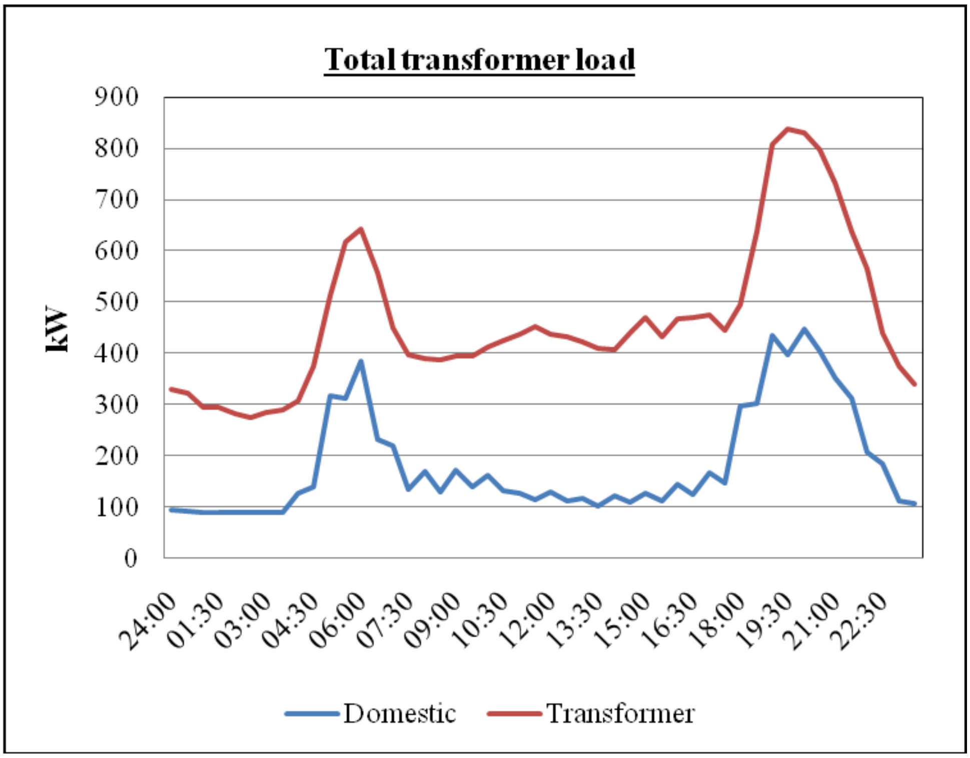

Figure 7: Comparison between actual power consumption and estimated power consumption - total transformer load

Total load on transformers is contributed not by the households only, but it consists of the consumption by the commercial buildings, small enterprises as well as the street lights of the area. The areas under the two graphs give the electrical energy consumptions of the two cases. It reveals that household consumption is 39% of the transformer energy consumption. This figure is almost the same as the national figure for the household electrical energy consumption and thus it is obvious that the information gathered from the questionnaire is accurate to a large extent.

Actual power consumption of 11 individual houses of the main sample was also monitored by fixing power analyzers and those readings were compared with the data obtained from the residents in those houses through questionnaire (see Annex 1). Figure given below illustrates the comparison between two figures.

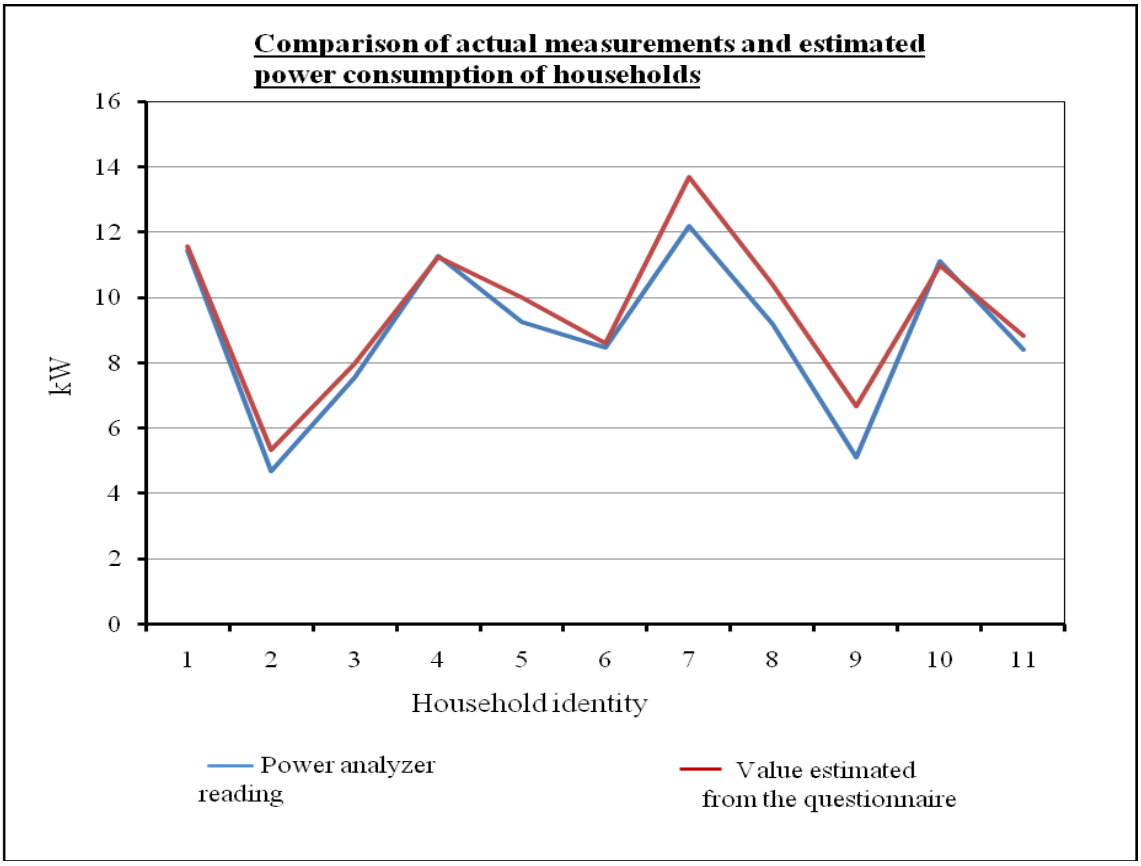

Figure 8: Comparison between actual power consumption and estimated power consumption - of individual households

From the above it is further verified that the average deviation of the data obtained from the questionnaire is less than 6.

4.0 ENERGY CONSCIOUSNESS

The consciousness for energy saving and knowledge on energy conservation tips were also studied during the survey. The information obtained through the responses of the surveyed households is summarized as below:

Table 7: Response of residents on energy saving practices

Content of the Questionnaire	**Total no. of houses**	**Percentage %**
Number of households following any strategy for saving electricity	2316	93%
Number of households **not** following any strategy for saving electricity	173	7%
Households that saved electricity by practicing below mentioned strategies		
Replacing Incandescent lamps with CFLs usage	1836	80%
Changing the ironing pattern	836	36%

Applying soft colours on walls	1223	53%
Changing refrigerator usage pattern	394	17%
Use of small refrigerator	355	15%
Use of table lamps	172	7%
Switch off unnecessary lamps	1662	72%
Use of low wattage lamps at night	786	34%
Switch off unnecessary lamps when watching TV	1421	61%
Turn off TV only from the remote controller	1589	69%
Remove the chargers from the plug after charging	1360	59%
Proper maintenance of electric equipments	779	34%

It shows that 93% of the total number of households in the sample are aware of energy saving and its importance, and therefore practicing energy saving strategies. Replacement of Incandescent lamps with CFLs also seems to be a common practice. The responses of the people were analyzed sector wise and attached as Annex 3. Highest positive responses on energy saving has received from the urban sector, and it is deemed due to increased awareness in urban sector residents. Above information will be further used for formulating approaches for awareness programmes.

CONCLUSION

As mentioned above efforts should be taken to reduce the peak loads that occur during morning and evening. Evening peak is more dominated than the morning peak. There is significantly high contribution from the ironing load, and efforts should be taken to induce residents to shift ironing to another convenient time of the day. Lighting load is the most dominant during evening peak accounting 43% of the evening peak load. Main lighting sources are CFLs and incandescent lamps and it is observed that the number CFLs and incandescent of lamps in use are almost similar in general. However CFLs in urban and semi-urban sectors are considerably higher than the incandescent lamps and this is opposite in rural sector. By replacing the existing incandescent lamps with CFLs, total lighting load during evening peak could be reduced by 40% which accounts nearly 90 kW.

Annex 1:

Selected Transformer	Transformer No.	Account No.	Electricity consumption according to the power analyzer measurements		Electricity consumption according to the information gathered from the questionnaire	
			kW	kWh	kW	kWh
1	M 101	4300052204	11.43	5.715	11.58	5.79
		4393822315	4.68	2.34	5.32	2.66
2	M 119	4395266711	7.57	3.785	7.98	3.99
		4304757601	11.28	5.64	11.25	5.625
3	M 142	4304373706	9.24	4.62	10	5
4	M 109	4309149103	8.46	4.23	8.61	4.305
		4395816312	12.2	6.1	13.7	6.85
5	M 132	4300866805	9.19	4.595	10.4	5.2
		4397052417	5.12	2.56	6.67	3.335
6	M 488	4394102111	11.12	5.56	10.97	5.485
		4307326202	8.42	4.21	8.82	4.41

Annex 2:

Sector	Rural		Semi Urban		Urban	
	No. of houses	**%**	**No. of houses**	**%**	**No. of houses**	**%**
Number of households following any strategy for saving electricity	1515	93%	610	91%	191	96%
Number of households **not** following any strategy for saving electricity	109	7%	57	9%	7	4%
Replacing Incandescent lamps with CFLs usage	1136	75%	532	87%	168	88%
Changing the ironing pattern	529	35%	249	41%	58	30%
Applying soft colours on walls	790	52%	320	52%	113	59%
Changing refrigerator usage pattern	225	15%	127	21%	42	22%
Use of small refrigerator	206	14%	107	18%	42	22%
Use of table lamps	108	7%	51	8%	13	7%
Switch off unnecessary lamps	1108	73%	426	70%	128	67%
Use of low wattage lamps at night	501	33%	233	38%	52	27%
Switch off unnecessary lamps when watching TV	926	61%	388	64%	107	56%
Turn off TV only from the remote controller	1030	68%	425	70%	134	70%
Remove the chargers from the plug after charging	865	57%	374	61%	121	63%
Proper maintenance of electric equipments	491	32%	237	39%	51	27%

Annex 3:

Transformer No.		No. of responses									
		107	**475**	**132**	**473**	**119**	**451**	**142**	**101**	**109**	**488**
No. of houses using CFLs		328	180	195	212	264	151	168	96	313	61
Reason for using CFLs	Low price	14	17	32	6	25	15	6	11	45	4
	Colour	62	31	57	25	65	49	26	28	72	13
	Warranty	178	124	104	133	170	87	97	60	204	32
	Long operation time	88	59	81	68	90	55	56	36	106	25
	Low electricity consumption	270	144	178	196	224	110	157	84	285	55
Facts you consider when buying a CFL	Colour	55	32	55	27	63	47	25	29	66	12
	Price	63	53	66	54	62	45	45	33	82	10
	SLS certificate	106	57	90	96	112	48	53	35	140	17
	Warranty	265	144	155	188	216	128	154	76	257	51
	Energy label	48	24	48	37	44	20	18	22	85	6
	Shape	14	6	22	8	18	9	4	11	32	5
No. of houses which does not use CFLs		119	14	39	60	61	79	67	26	50	13
Reason for not using CFLs	High price	69	11	24	38	29	45	36	17	21	4
	Not like the colour	8	0	3	3	2	1	5	2	1	0
	Not common in the market	16	1	3	6	5	14	12	4	5	0
	Quickly burn	31	10	5	23	16	34	30	10	10	3
	Bad for health	2	1	2	0	1	1	2	1	1	0

Annex 4:

Sector		Rural		Semi Urban		Urban	
		No. of houses	%	No. of houses	%	No. of houses	%
No. of houses using CFLs		1219	74.7%	569	84.8%	180	92.8%
Reason for using CFL	Low price	77	6.3%	81	14.2%	17	9.4%
	Colour	255	20.9%	142	25.0%	31	17.2%
	Warranty	725	59.5%	340	59.8%	124	68.9%
	Long operation time	393	32.2%	212	37.3%	59	32.8%
	Low electricity consumption	1041	85.4%	518	91.0%	144	80.0%
Facts you consider when buying a CFL	Colour	246	20.2%	133	23.4%	32	17.8%
	Price	302	24.8%	158	27.8%	53	29.4%
	SLS certificate	450	36.9%	247	43.4%	57	31.7%
	Warranty	1027	84.3%	463	81.4%	144	80.0%
	Energy label	189	15.5%	139	24.4%	24	13.3%
	Shape	64	5.3%	59	10.4%	6	3.3%
No. of houses which does not use CFLs		412	25.3%	102	15.2%	14	7.2%
Reason for not using CFLs	High price	234	56.8%	49	48.0%	11	78.6%
	Not like the colour	21	5.1%	4	3.9%	0	0.0%
	Not common in the market	57	13.8%	8	7.8%	1	7.1%
	Quickly burn	144	35.0%	18	17.7%	10	71.4%
	Bad for health	7	1.7%	3	2.9%	1	7.1%